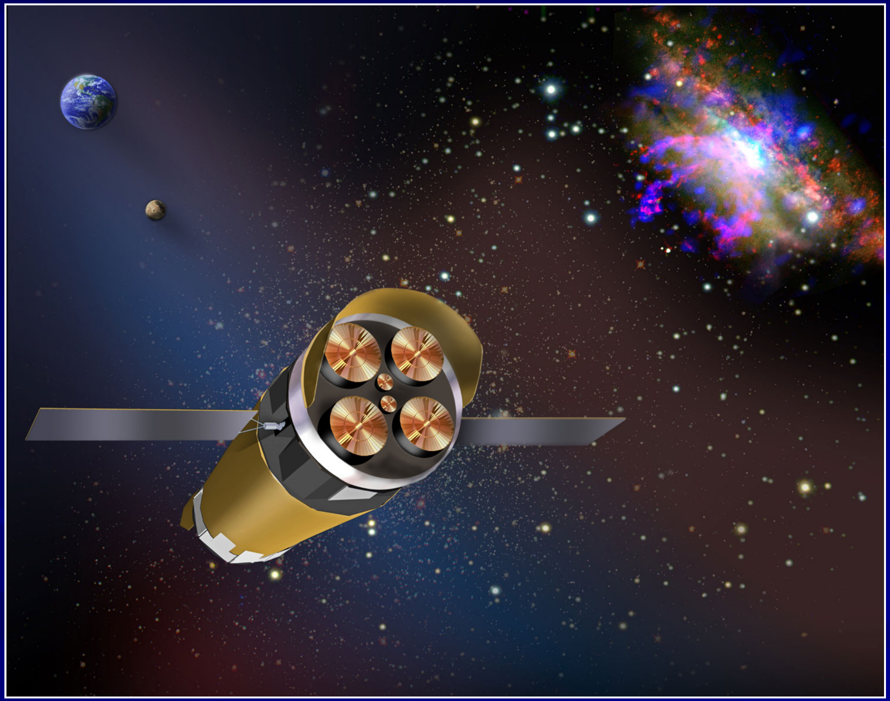
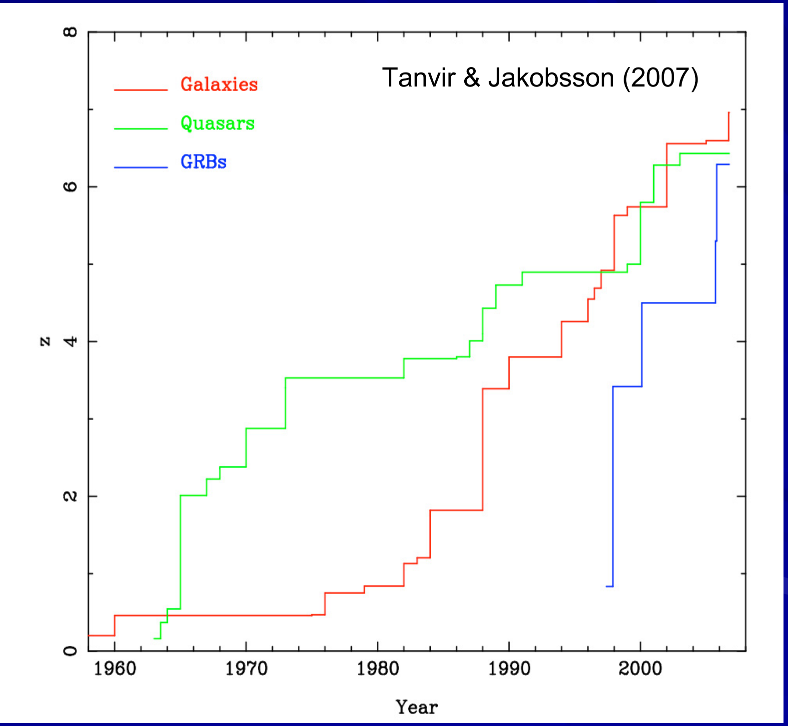
Exploring the High-Redshift X-ray Universe with Constellation-X

Niel Brandt for the High-Redshift Science Panel





Available Con-X targets at z ~ 4-10 are AGNs and GRBs.

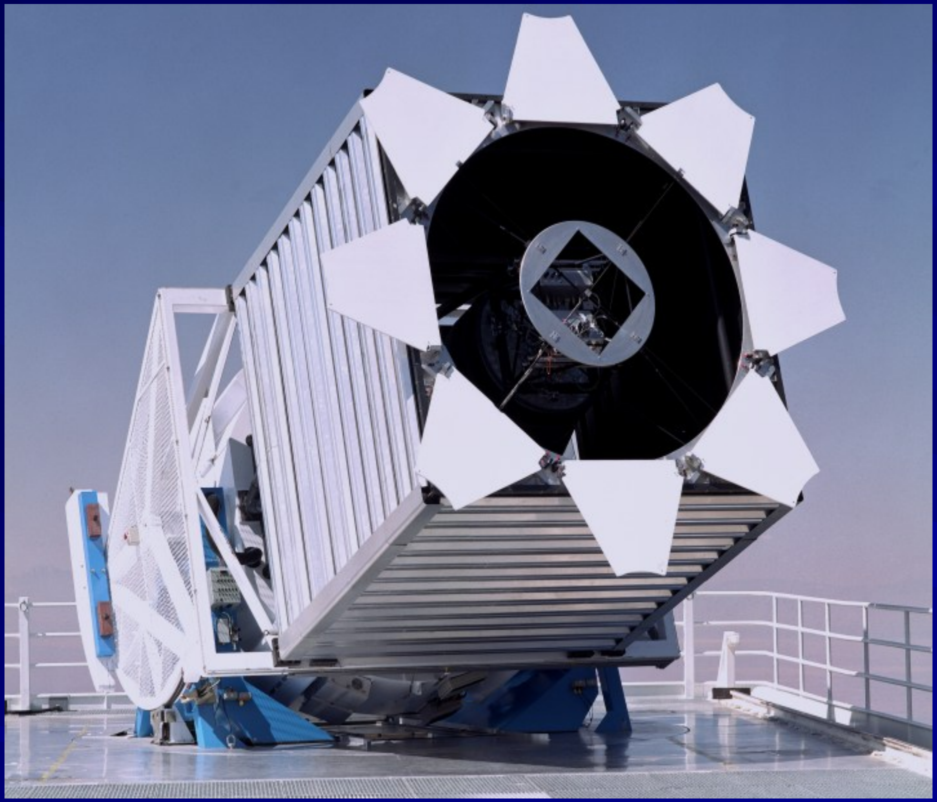
Science Panel Members

Niel Brandt
Kathy Flanagan
Neil Gehrels
George Ricker
Elena Rossi
Ohad Shemmer
Rachel Somerville
Massimo Stiavelli
Cristian Vignali

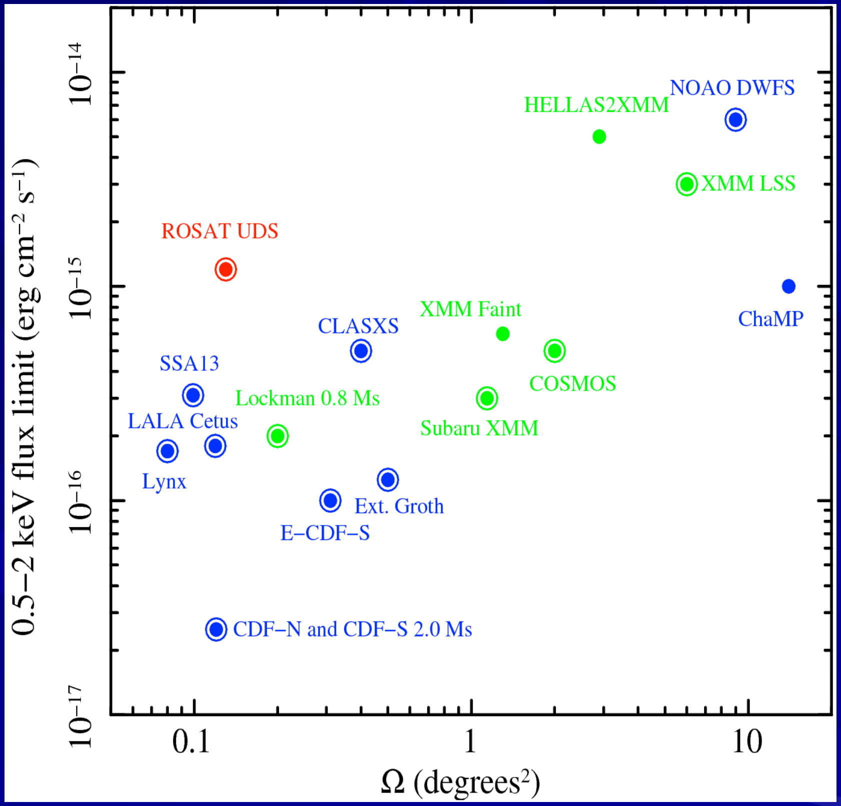
Highest Redshift AGNs: Current X-ray Understanding

Growing Population of z > 4 AGNs

Optical Selection - e.g., SDSS



X-ray Selection

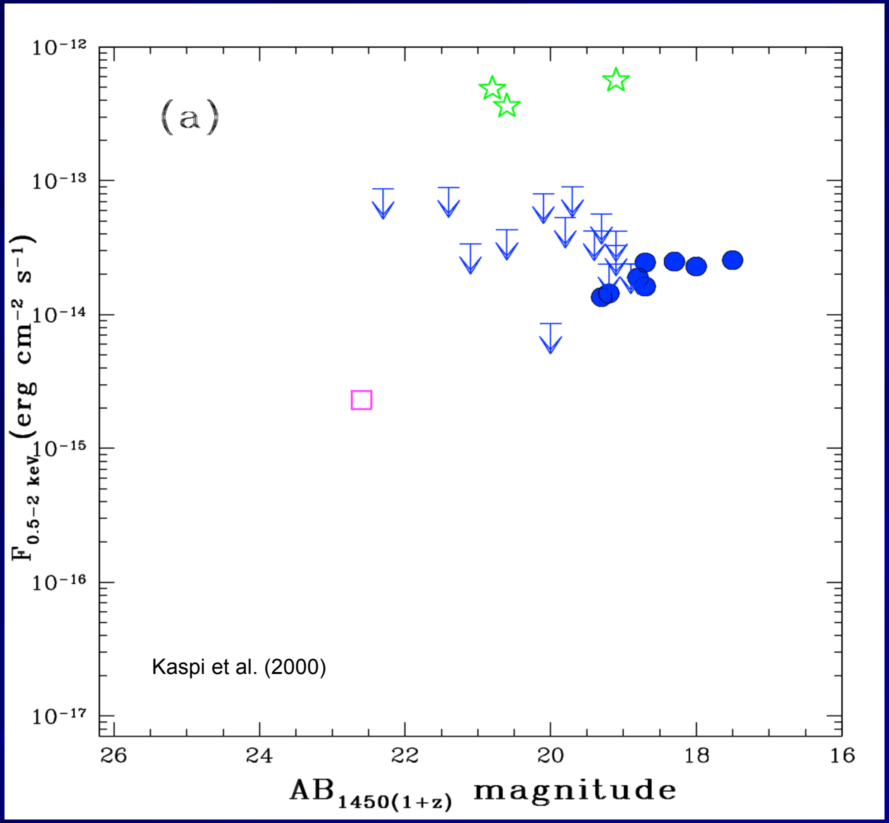


Wide-field optical surveys have delivered many rare, luminous quasars up to z ~ 6.43.

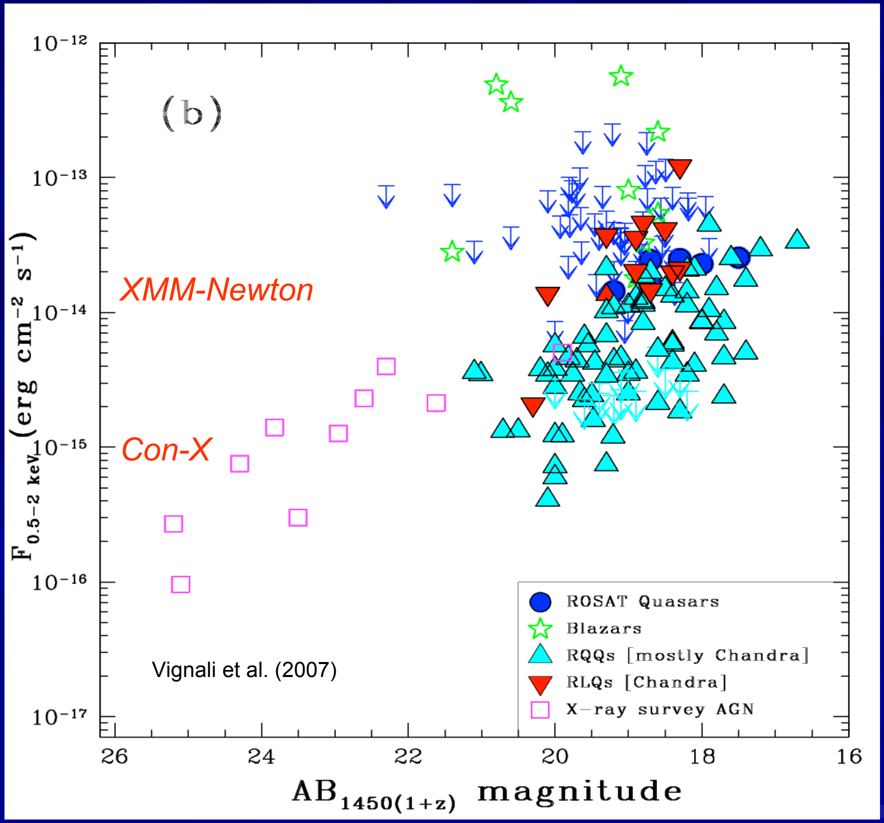
Deep X-ray surveys have delivered some moderate-luminosity AGNs at z ~ 4-5.4.

Advances in X-ray Studies at z > 4

Status in 2000



Present Status



More than tenfold enlargement in number of X-ray detected AGNs at z ~ 4-6.4.

Spectroscopy difficult presently due to low X-ray fluxes - XMM-Newton.

Key Science Goals

Accretion Mechanisms

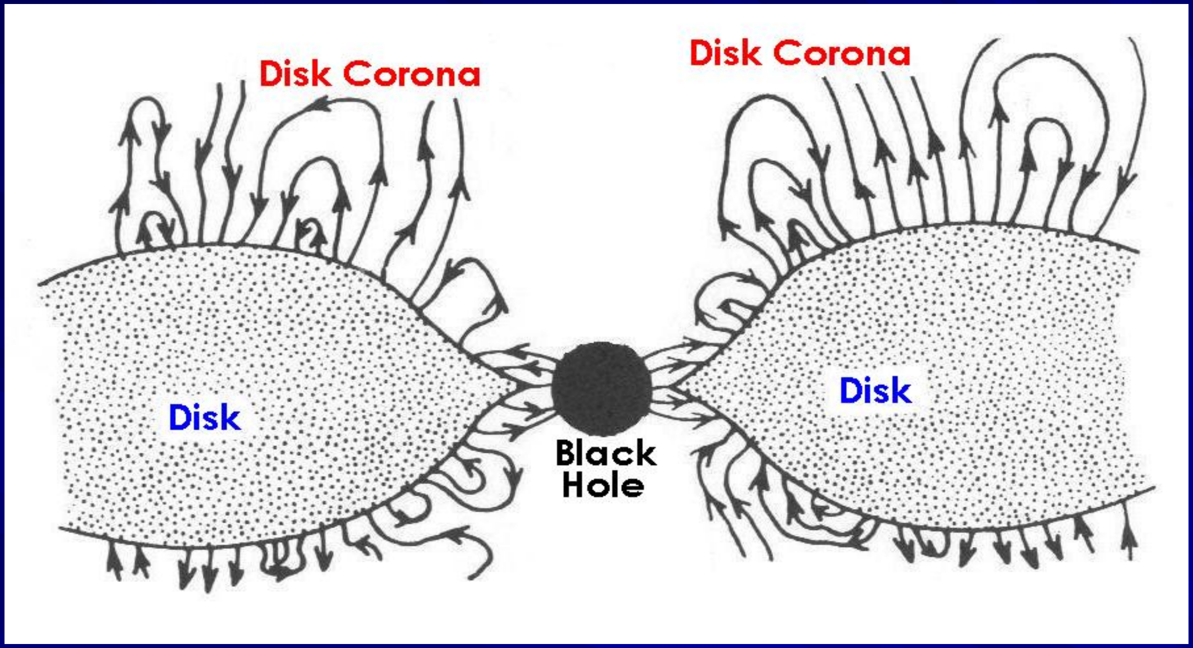
Are first SMBHs feeding and growing in same way as local ones?

Environments

What are environments of first AGNs?

How do they influence first galaxies and IGM?

Accretion Mechanisms

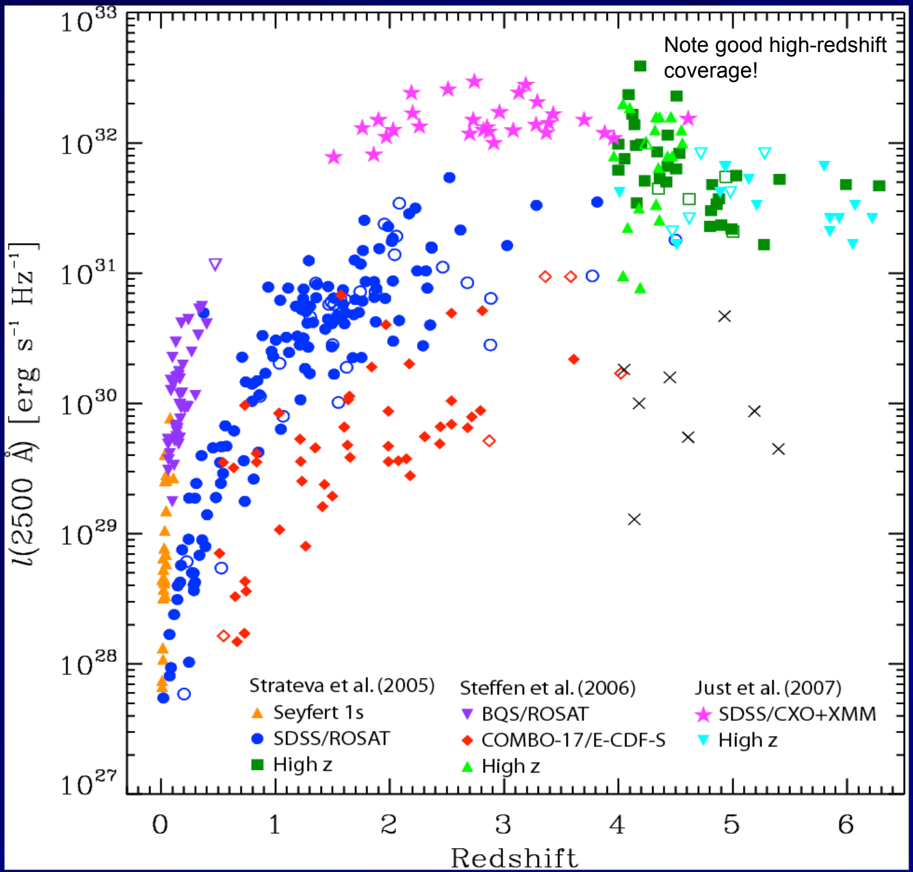


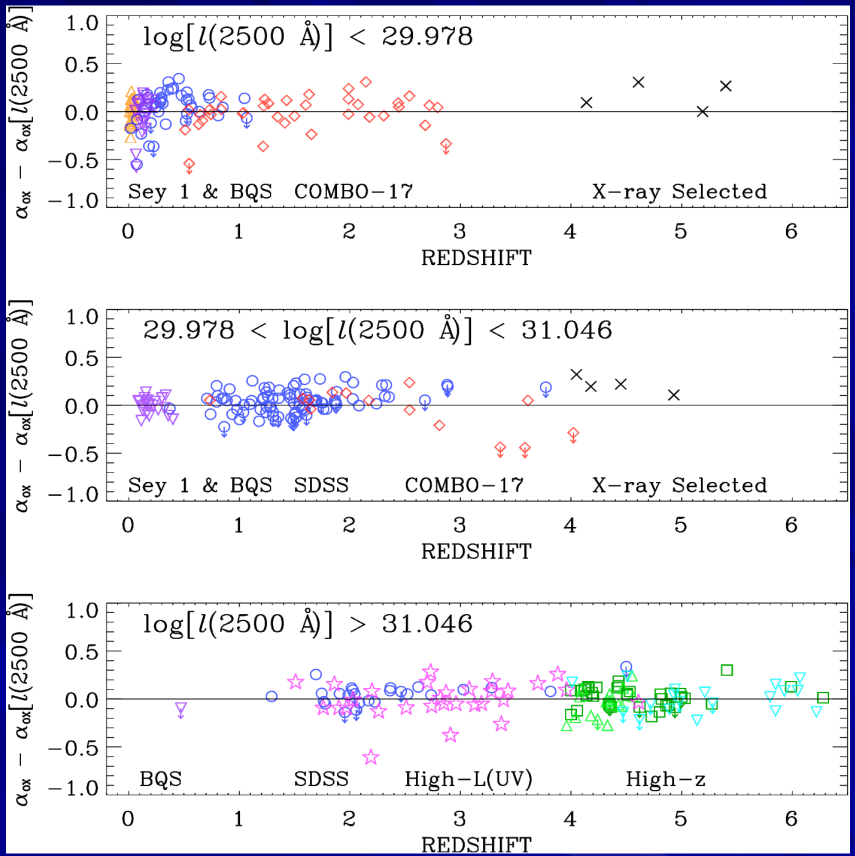
Changes in L / L_{Edd} have associated X-ray spectral changes.

Rapid growth of first SMBHs by super-Eddington accretion?

Claims and counterclaims about spectral changes in literature.

Accretion Mechanisms - X-ray-to-Optical





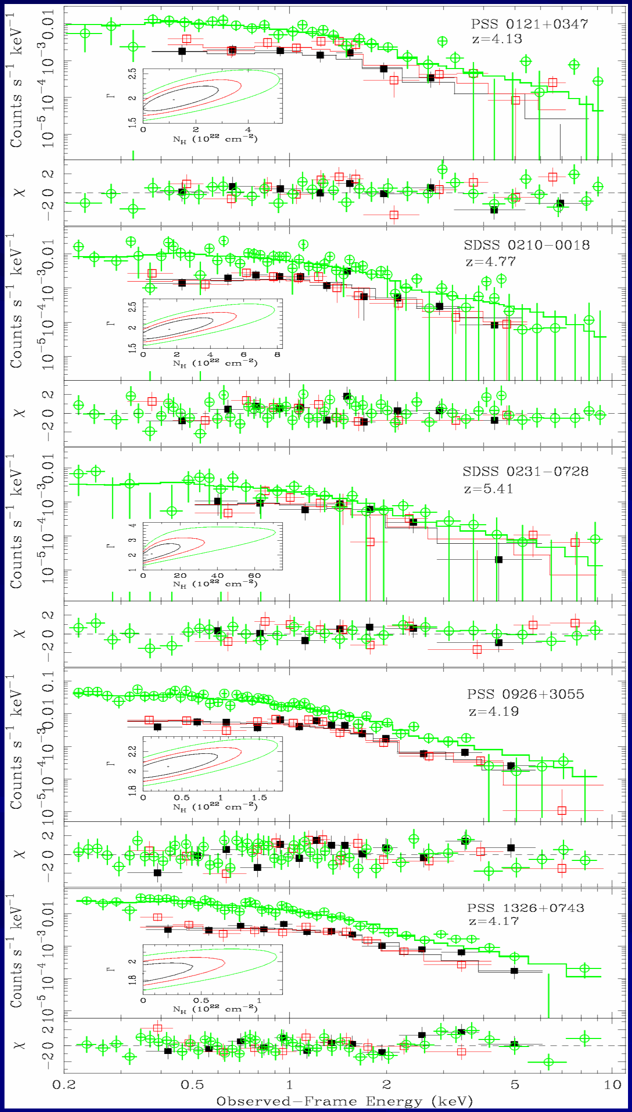
Combined AGN samples now span much of luminosity-redshift plane.

X-ray emission at z ~ 4-6.4 is there at about expected level - good for Con-X.

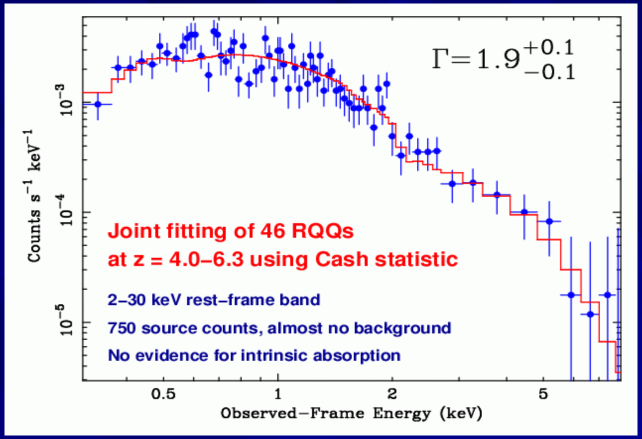
X-ray-to-optical flux ratios change by < 30% from z = 0-6.

Accretion Mechanisms - X-ray Spectra

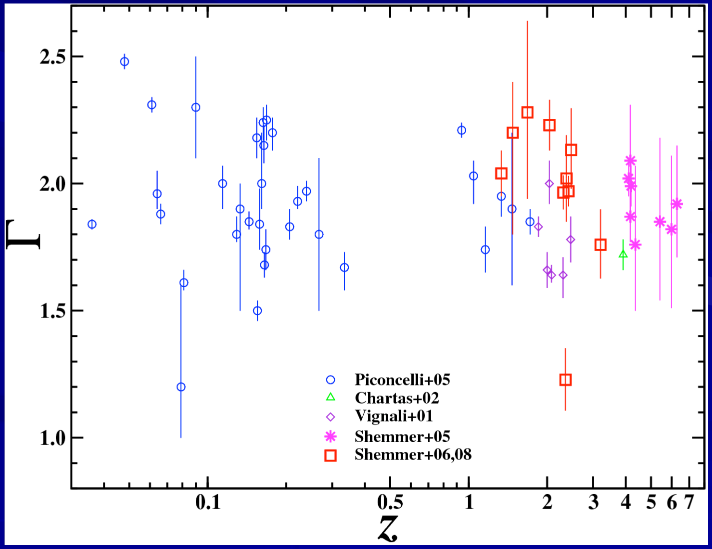
XMM-Newton Spectra - Shemmer et al. (2005)



Chandra Joint Fitting - Vignali et al. (2005)

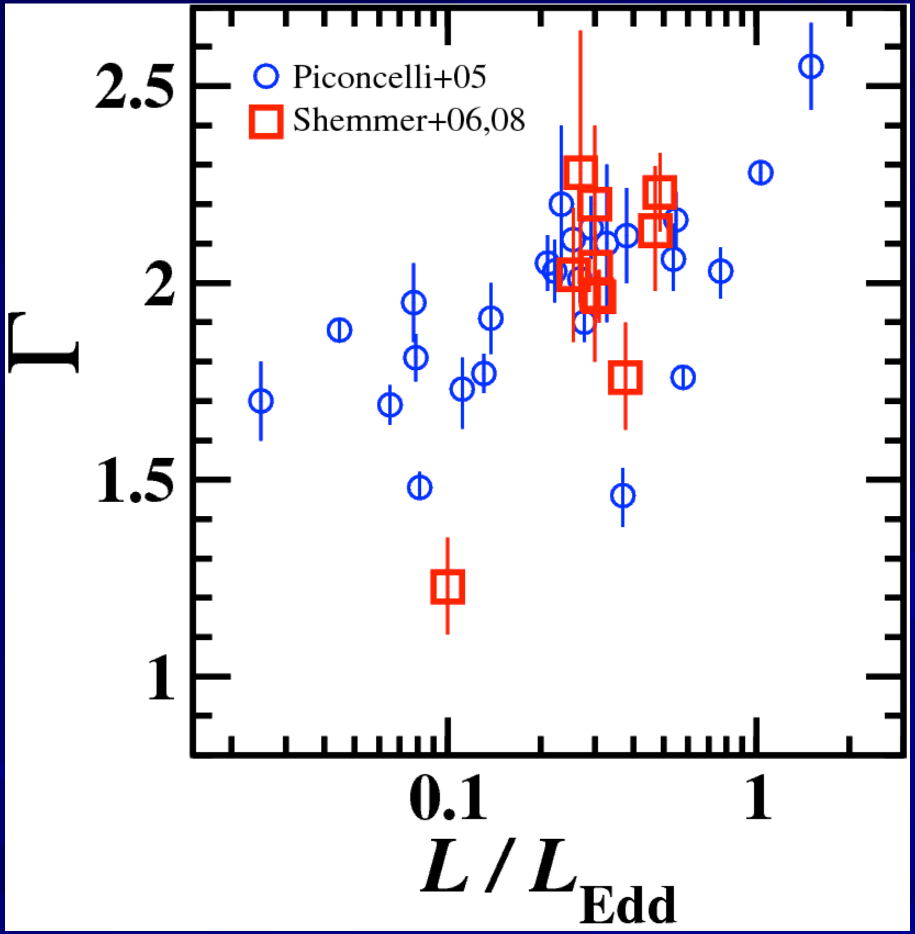


Photon index has intrinsic scatter, but no redshift dependence



Generally no detectable reflection “humps” or iron K lines - limits weak.

L / L_{Edd} from Hard X-ray Spectrum



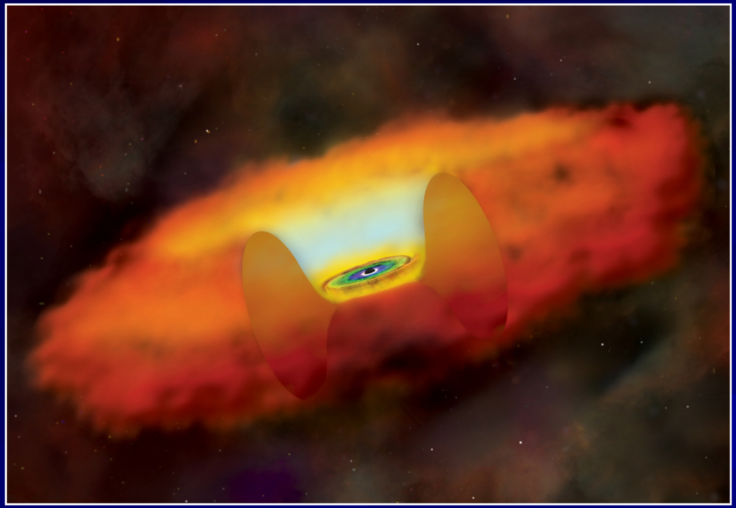
Photon index of hard X-ray power law correlates with normalized accretion rate for luminous AGNs (~ 10^3 luminosity range).

Cooling of disk corona?

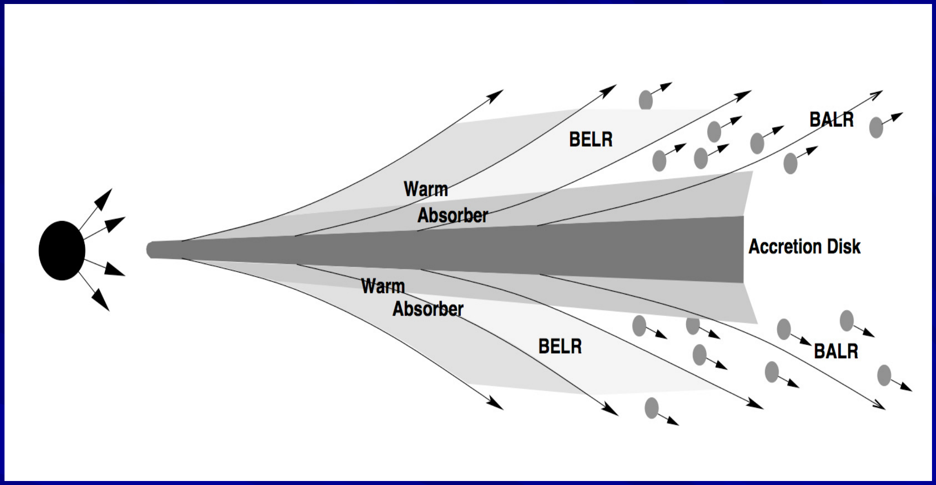
L / L_{Edd} estimates with factor ~ 3 uncertainty.

X-ray based method by which Con-X could assess SMBH growth at highest redshifts.

Environments

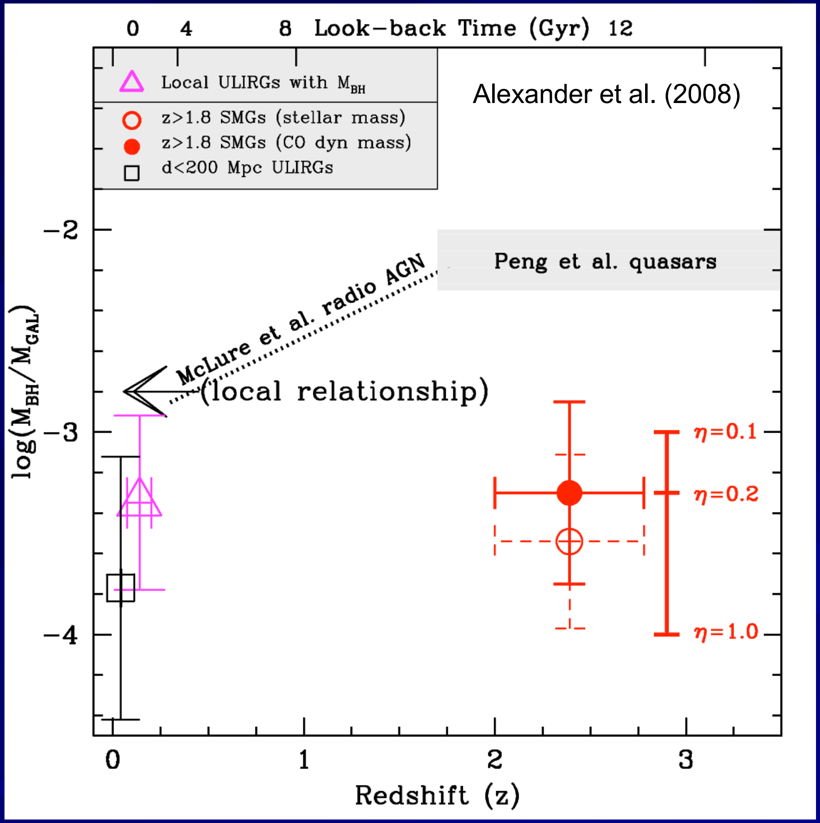


Obscuration

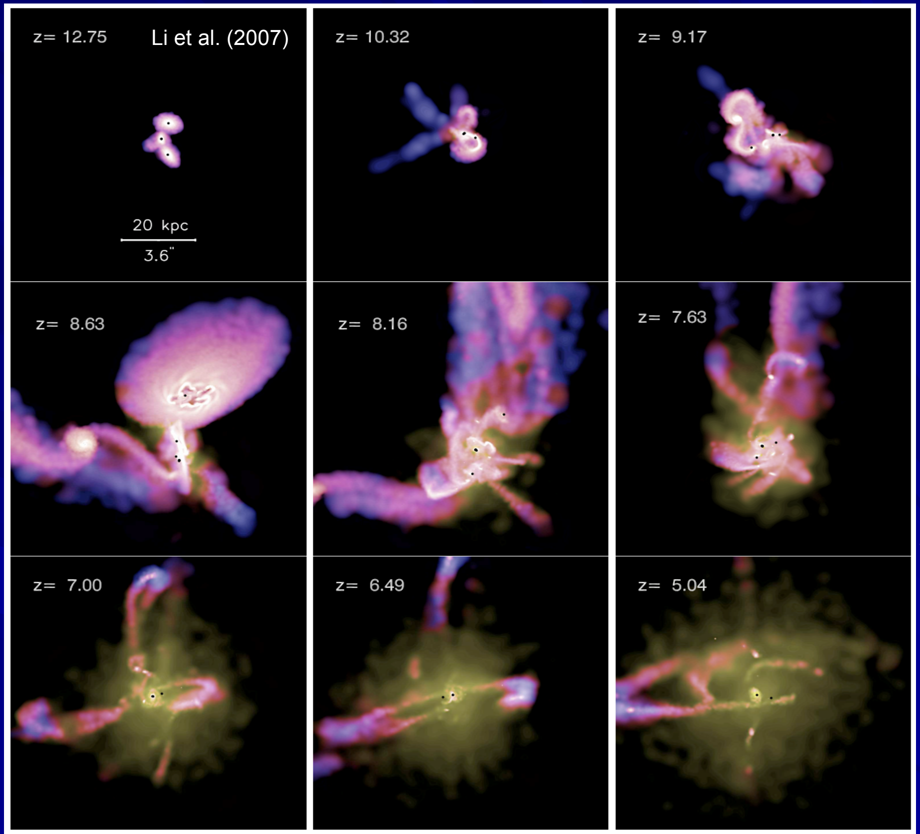


Outflows and their Effects

Environments - First Galaxies



Gas density and temperature for high-redshift quasar host



Several studies of moderate-to-high redshift AGNs suggest M_{BH} / M_{Bulge} higher in past.

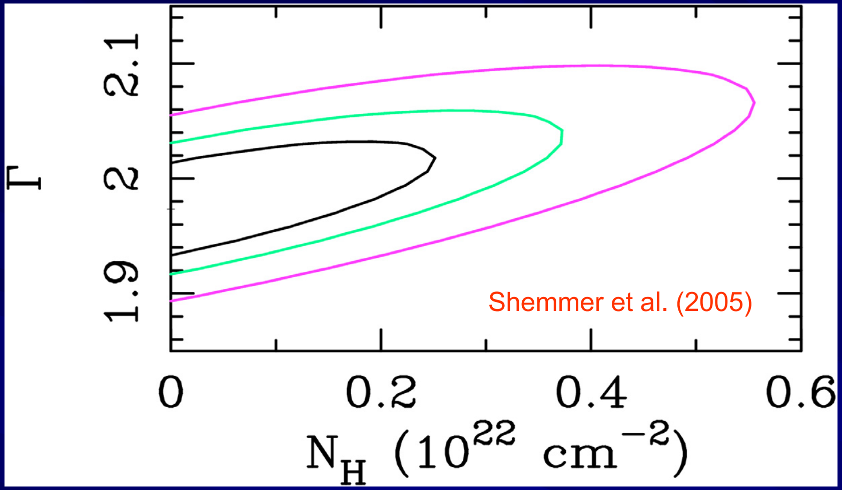
SMBH-driven outflows may be particularly potent at high redshift.

Gas-rich mergers common in most massive halos.

Strong circumnuclear obscuration that is ultimately removed by SMBH-driven outflow.

Environments - Radio-Quiet Quasars (RQQs)

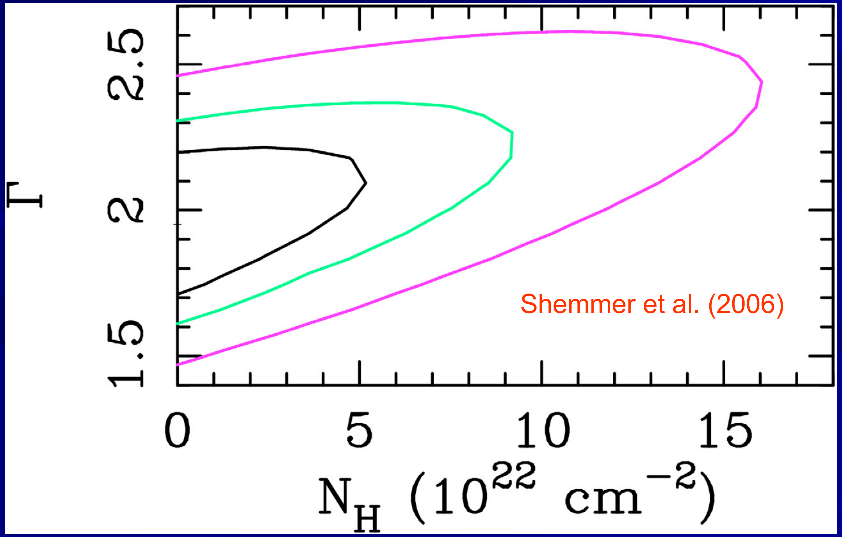
Joint XMM-Newton Fitting of 8 RQQs at z = 4.1-5.4



X-rays allow searches for both neutral and ionized matter.

Due to limited photons and redshifting of photoelectric absorption cut-off, constraints at highest redshifts currently limited.

Joint Chandra Fitting of 15 RQQs at z = 5.0-6.3

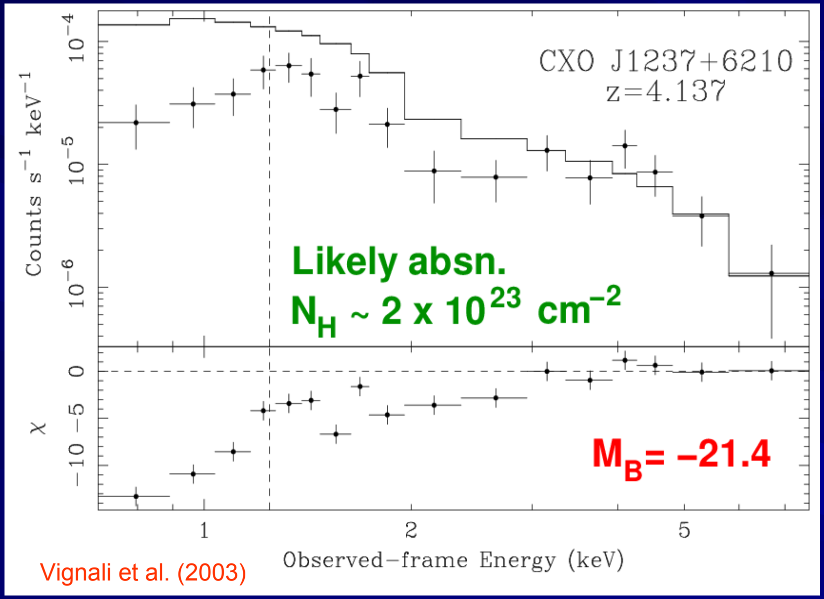


Joint spectral fitting shows no strong and widespread X-ray absorption in RQQs.

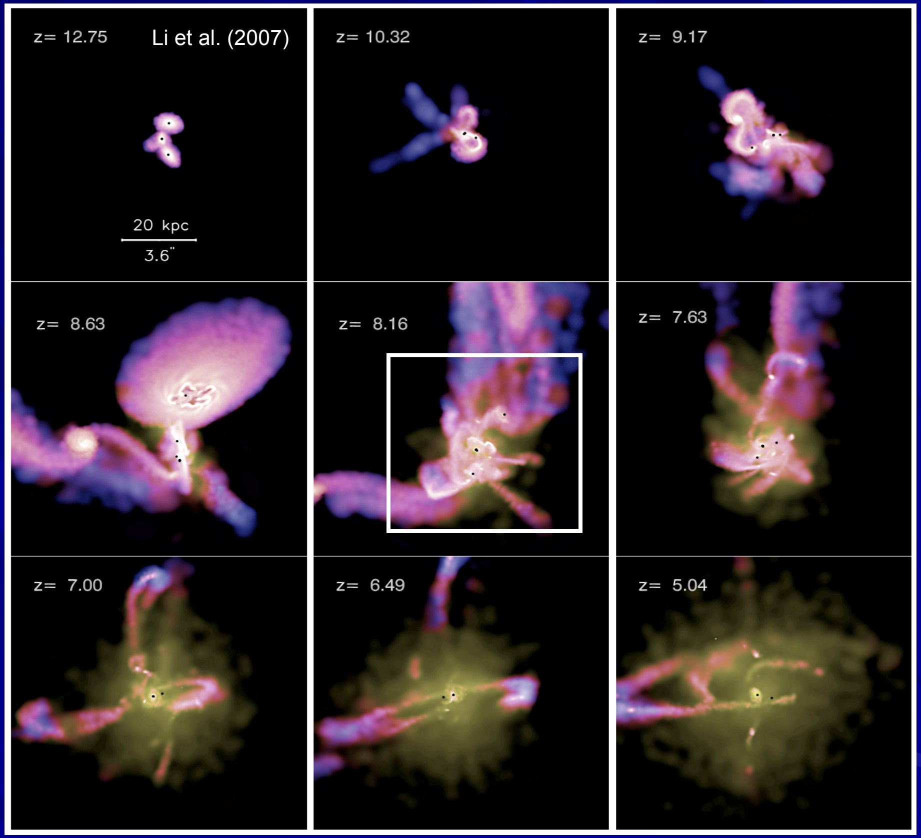
Ideally want to look for discrete X-ray absorption features with Con-X - lines and edges.

Environments - Radio-Quiet AGNs

Moderate-Luminosity AGN in Chandra Deep Field-North



Gas density and temperature for high-redshift quasar host

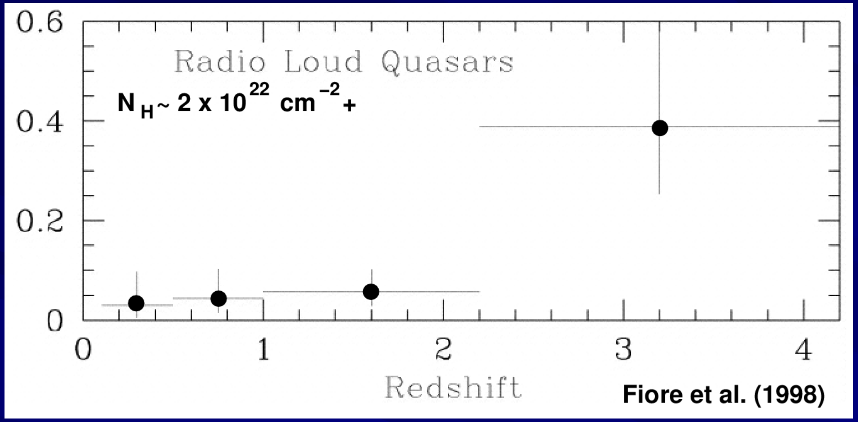


Spectral fitting with 2 Ms CDF-N data suggests strong X-ray absorption.

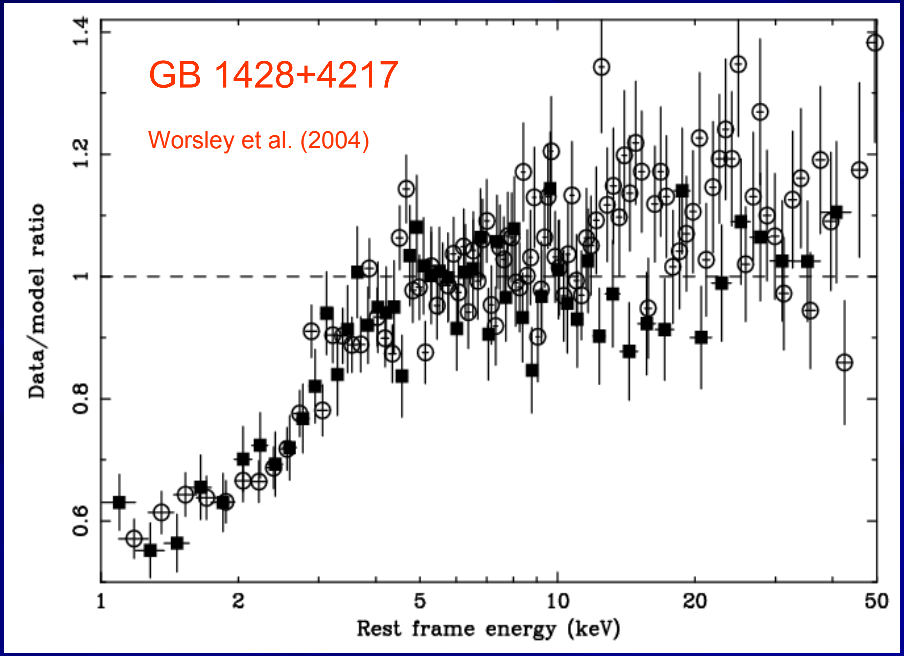
An obscured protoquasar?

Would like to measure composition, ionization, and dynamical state of absorption with Con-X.

Environments - Radio-Loud Quasars (RLQs)



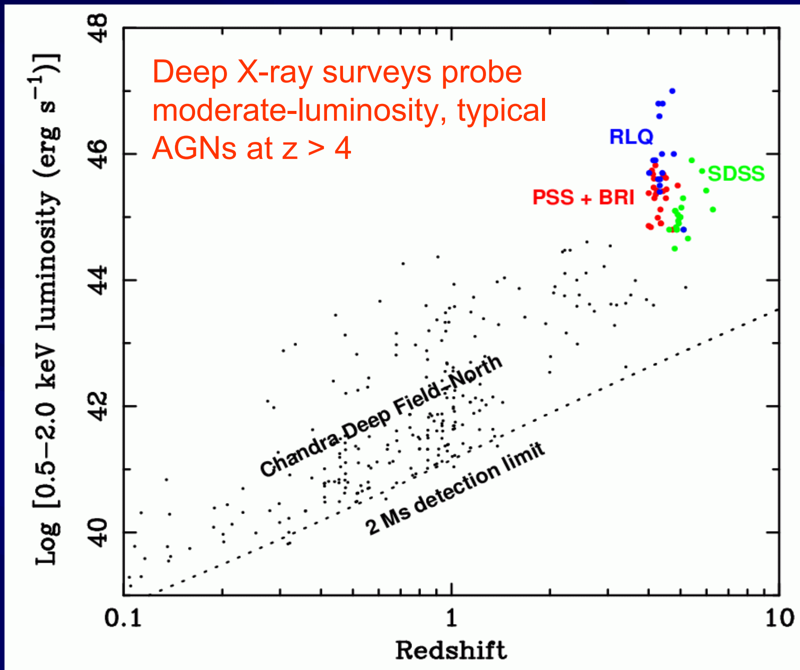
Fraction of RLQs with X-ray absorption appears to rise with redshift.

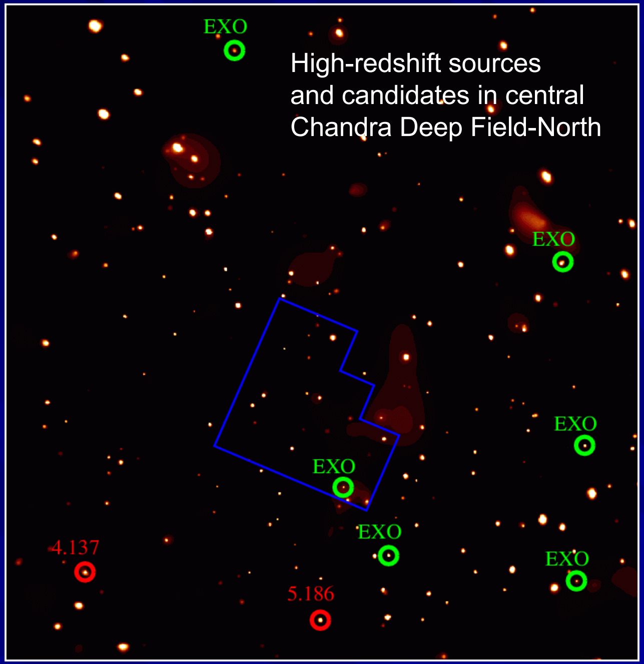


Trend continues at z ~ 4-5.

Circumnuclear? Young host? Entrained by jets?

Environments - Intergalactic Medium





Find or constrain sky density exploiting Lyman break.

Alexander et al. (01); Barger et al. (03); Cristiani et al. (04); Koekemoer et al. (04)

Sky density at z > 4 is ~ 30-150 deg^{-2}. About 800 times SDSS.

AGN contribution to reionization at z ~ 6 was small.

Supported by stacking of Lyman break galaxies and unresolved fraction of soft X-ray background.

May be diffuse X-ray heating of IGM at high redshift.

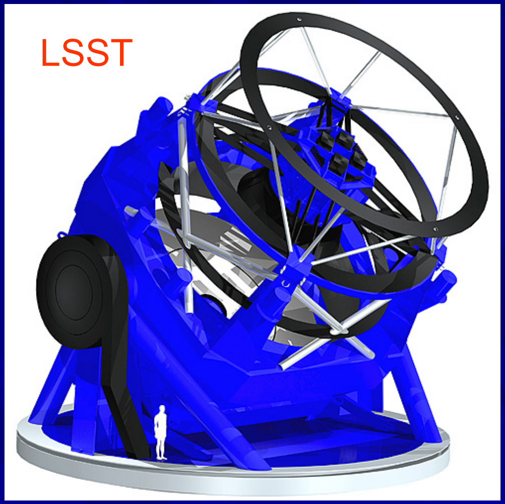
Table 1. Moderate-luminosity $z > 4$ AGNs found in X-ray surveys

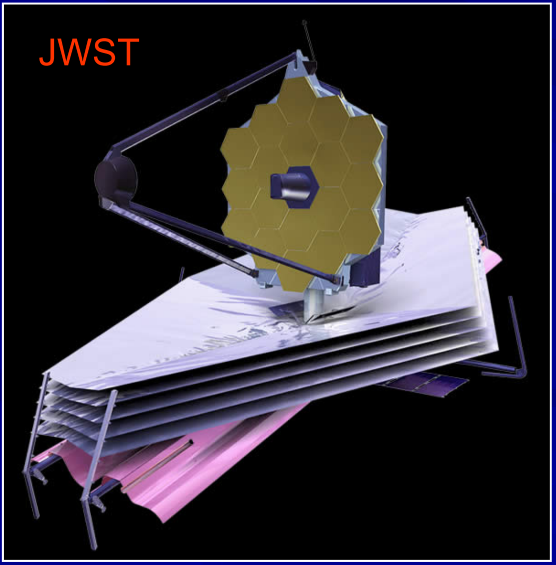
AGN name	Redshift	Rest-frame $\log(L_{2-10})$	Representative reference
CXOCY J033716.7 − 050153	4.61	44.54	Treister et al. (2004)
CLASXS J103414.33+572227	5.40	44.44	Steffen et al. (2004)
RX J1052 + 5719	4.45	44.72	Schneider et al. (1998)
CXOMP J105655.1 − 034322	4.05	44.92	Silverman et al. (2005)
CXOHDFN J123647.9 + 620941	5.19	44.00	Vignali et al. (2002)
CXOHDFN J123719.0 + 621025	4.14	43.72	Vignali et al. (2002)
CXOCY J125304.0 − 090737	4.18	44.39	Castander et al. (2003)
CXOMP J213945.0 − 234655	4.93	44.79	Silverman et al. (2002)

The third column above is the rest-frame 2–10 keV luminosity (in erg s^{-1}), computed using a power-law photon index of $\Gamma = 2$. We have only included AGNs in this table with $\log(L_{2-10}) < 45$. A few higher luminosity AGNs have also been found in X-ray surveys, such as RX J1028.6−0844 (Zickgraf et al. 1997) and RX J1759.4+6638 (Henry et al. 1994).

Highest Redshift AGNs: Con-X Prospects

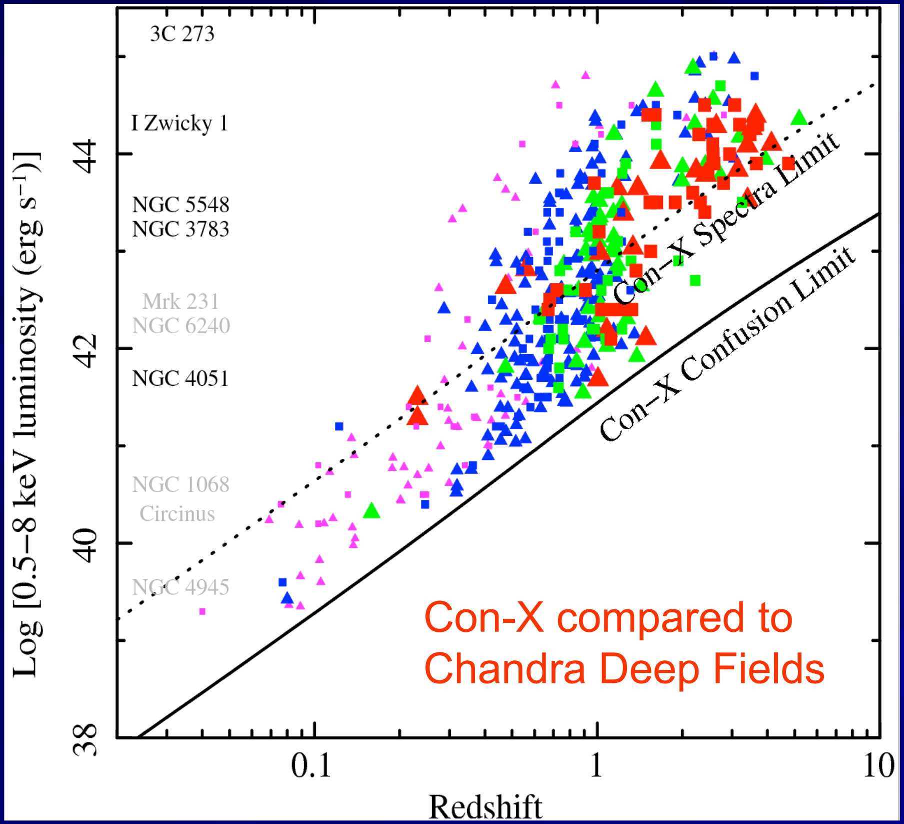
Abundant High-Redshift Targets for Con-X

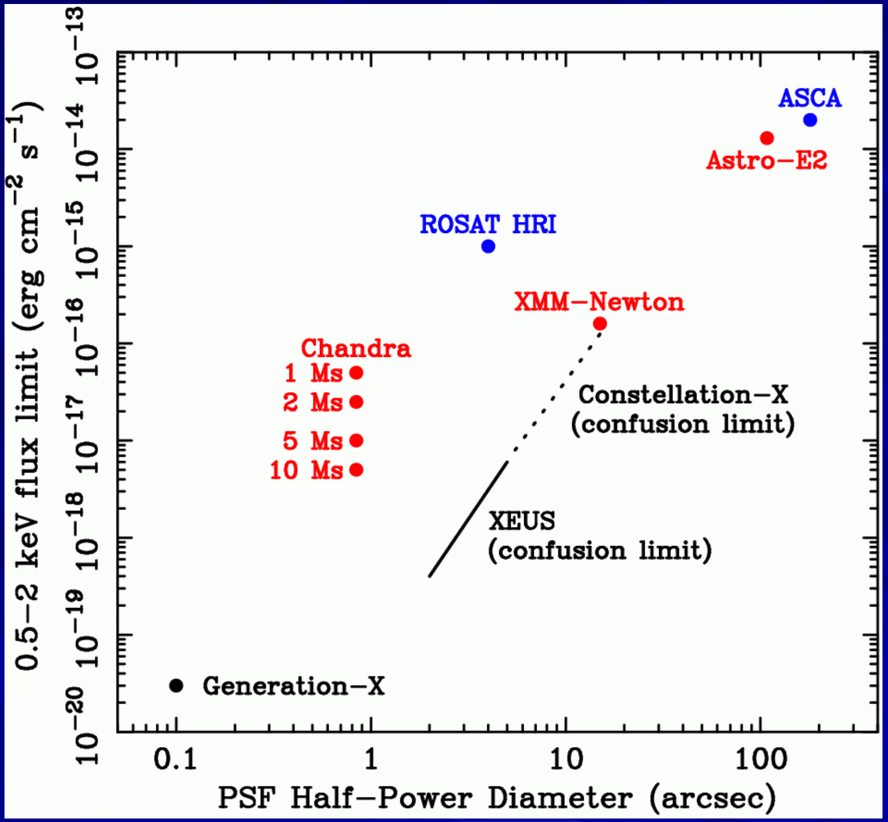




LSST alone will deliver ~ 1100 AGNs at z ~ 6.5-7.5

Flux and Black-Hole Mass Limits

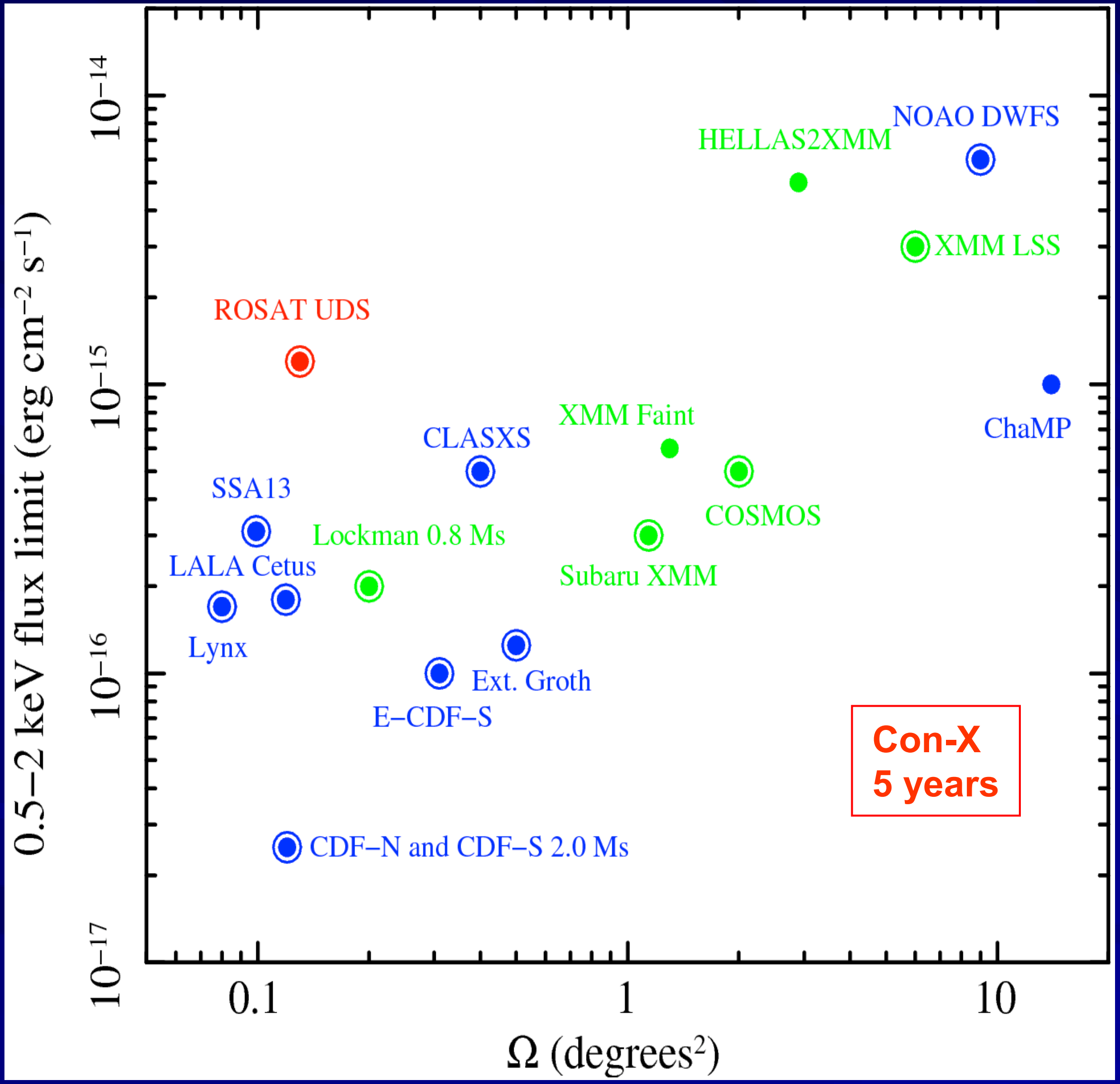




At z > 4, Con-X detects > 10^6 M_{Sun} holes and gets spectra for > $10^{7.5}$ M_{Sun} holes.

Can get good X-ray spectra for majority of optically identifiable Chandra Deep Field X-ray sources at z > 2-4.

Con-X Serendipitous Surveys at z > 4



Many Con-X observations should reach confusion limit.

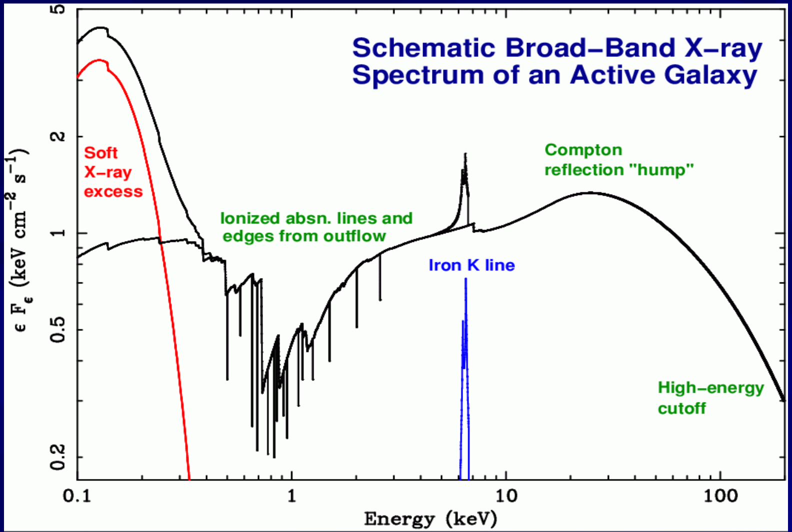
5-year AGN yield at z > 4 should be ~ 900.

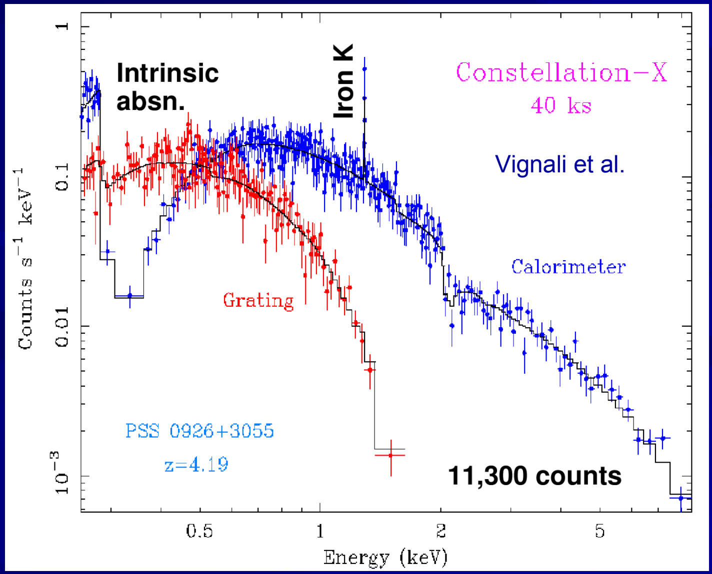
Can find obscured AGNs missed by other techniques.

Fe K line redshifts can help with identifications.

Reaching 5'' PSF goal would help greatly with yield and identifications.

Complex X-ray Spectra of AGNs





Current X-ray spectral constraints at z > 4 are generally crude (at most 500-1500 counts).

X-ray continuum shape

Intrinsic absorption

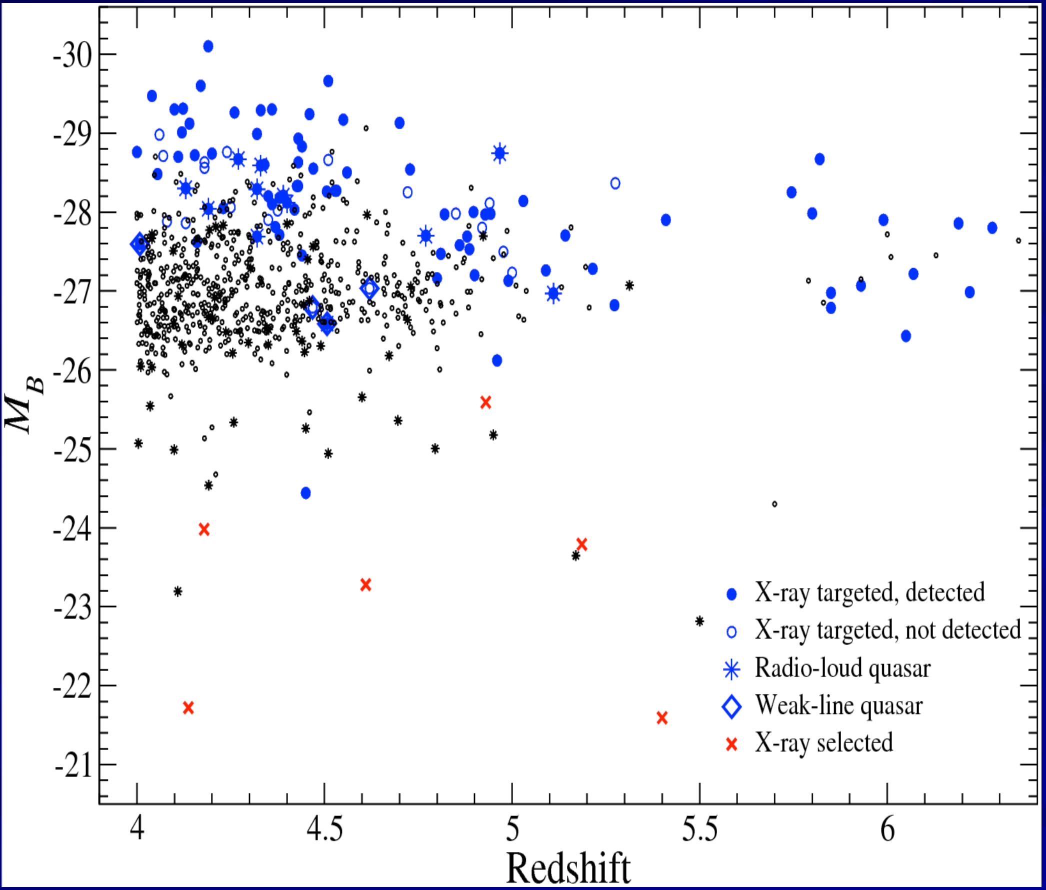
Iron K lines

Compton-reflection continuum

High-energy cut-off

Con-X High-Redshift AGN Program

Known and X-ray Observed AGNs at z > 4



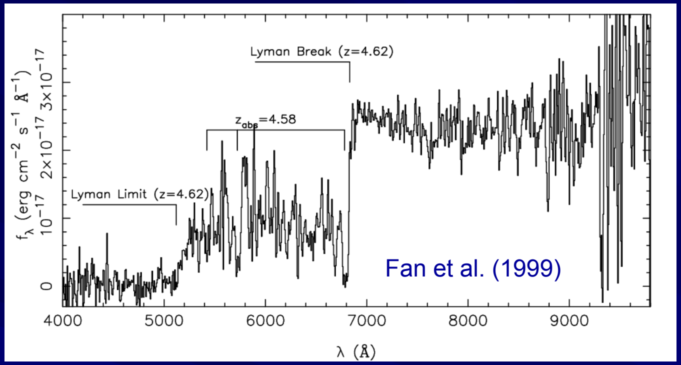
50-100 representative AGNs at z ~ 4-8 covering luminosity-redshift plane (2-4 Ms).

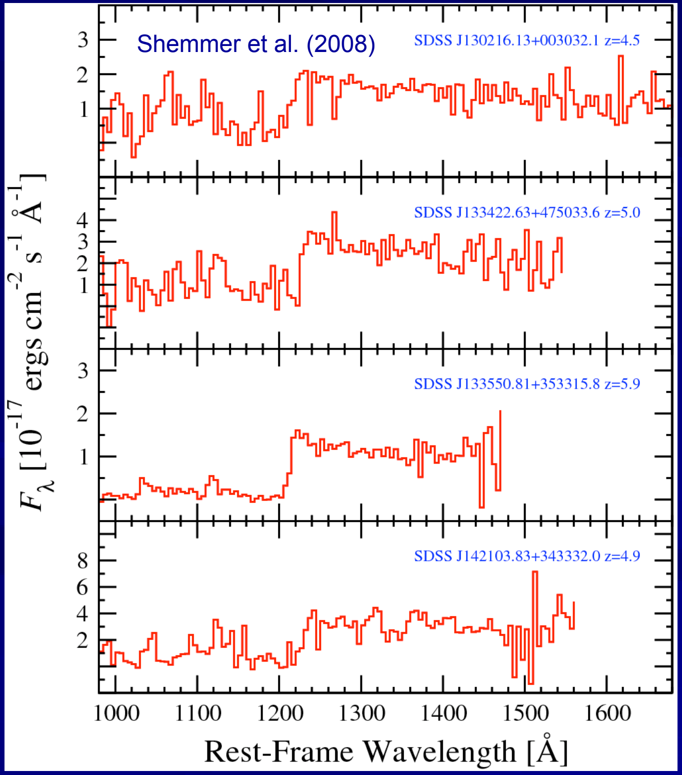
Deep exposures on ~ 10 luminous quasars at highest redshifts possible - templates for spectral understanding (2 Ms).

Remarkable high-redshift quasars - weak-line quasars, APM 08279+5255, etc. (2 Ms).

Serendipitous survey of obscured AGNs at highest redshifts (Free!).

Weak-Line Quasars at z > 4





Lyα + NV EWs < 5 Angstroms.

Some completely bereft of lines.

Selected by strong Lyman break.

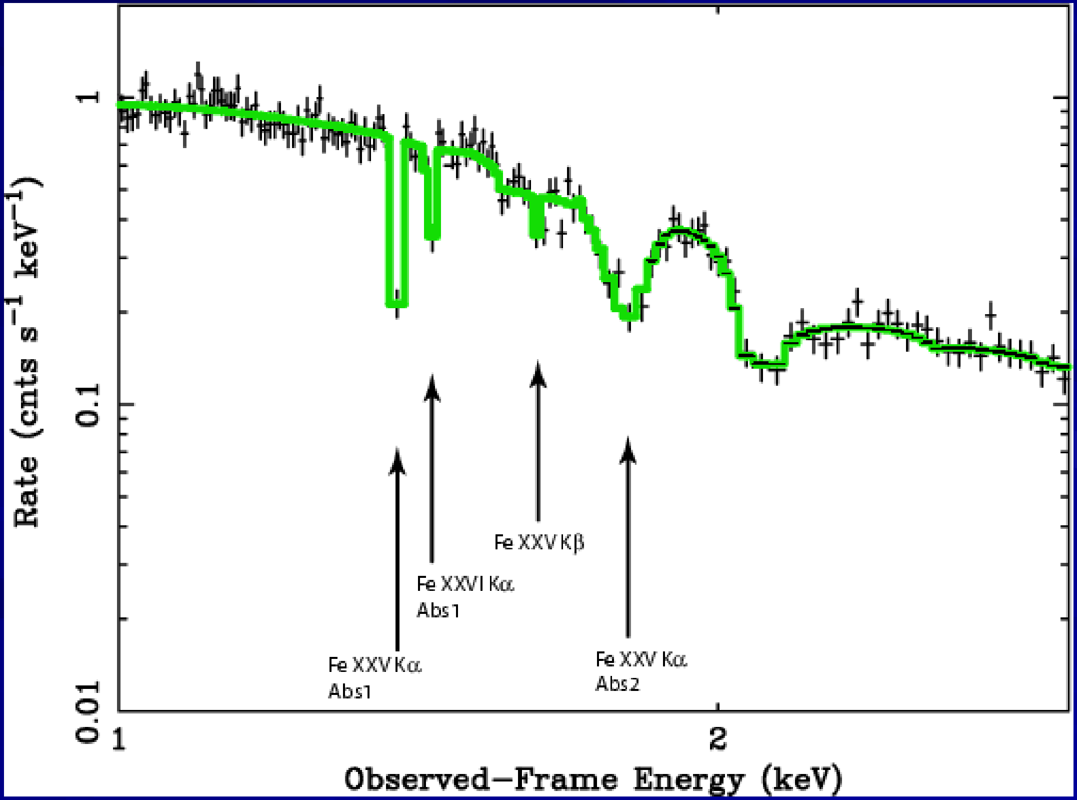
Often radio quiet and low polarization.

What has happened to their line emitting regions?

Con-X Simulation of APM 08279+5255

Simulated series of 10 ks Con-X observations, motivated by current Chandra and XMM-Newton data.

Variations of X-ray BALs should be straightforward to monitor, and can measure acceleration of absorbers over time.



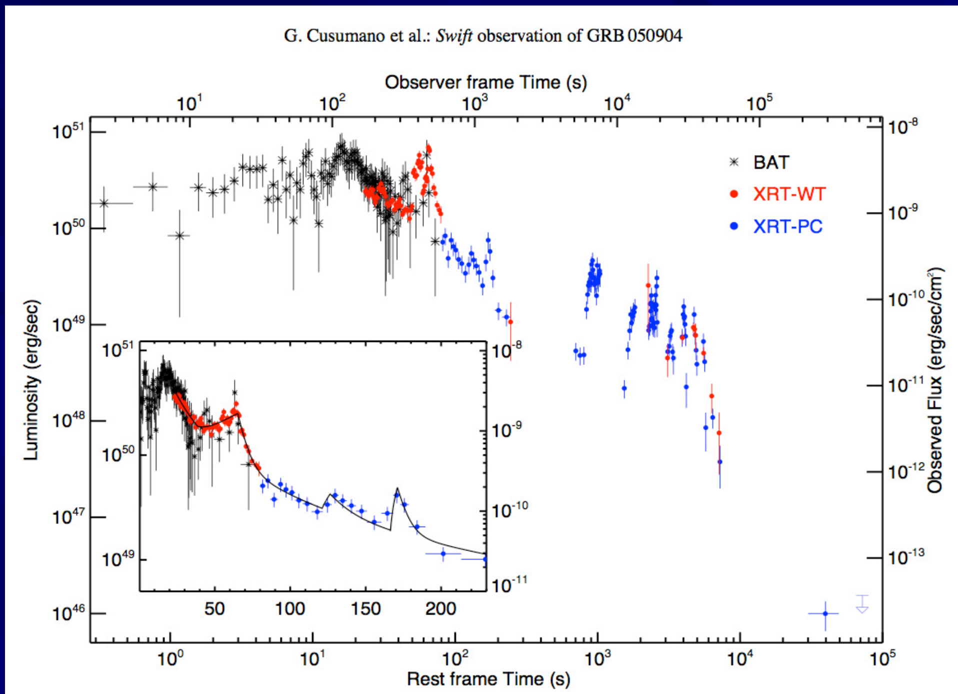
Chartas et al.

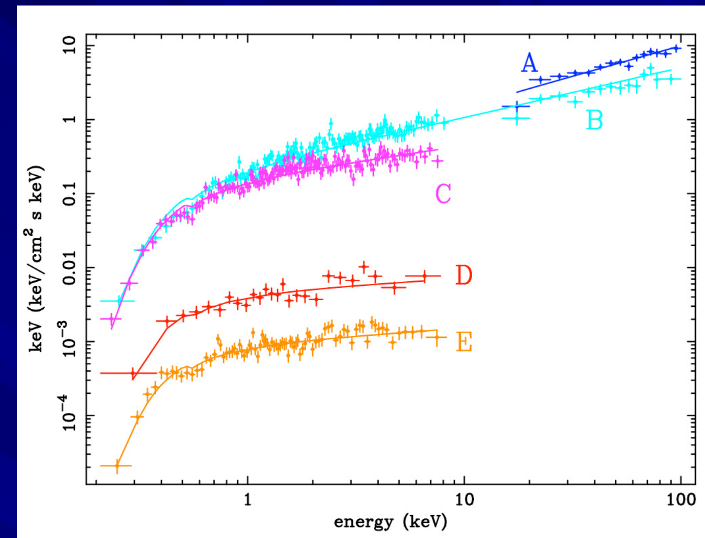
Highest Redshift GRBs

Basic Con-X Observational Approach

12-24 hrs. Can this be faster?

Variability of GRB 050904 at z = 6.29





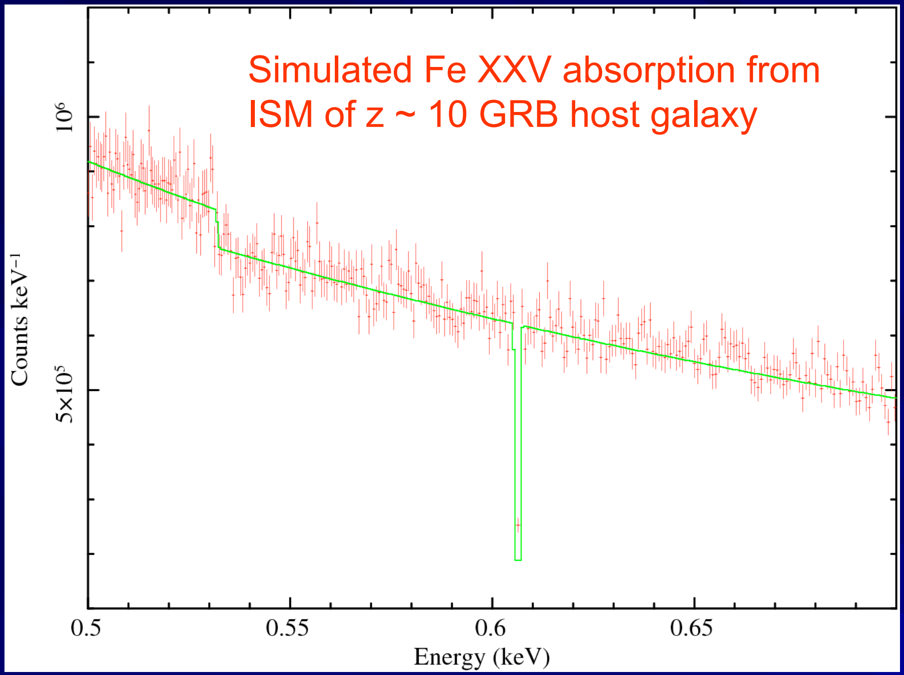
G. Cusumano et al.: *Swift* observation of GRB 050904

Interval	Time (s)		N_H (10^{22} cm^{-2})	Γ	χ^2_ν (dof)	Flux (10^{-9}erg cm^{-2} s^{-1})	
	Start	Stop			0.2–10 keV	15–350 keV	
BAT 1	−1.43	2.69	–	−1.2 ±0.4	1.2 (57)	1.4	22.9
2	2.69	4.89	–	−1.05±0.16	0.86 (57)	3.2	90.8
3	4.89	10.1	–	−1.36±0.21	0.97 (57)	3.4	30.9
4	10.1	20.4	–	−1.17±0.08	0.95 (57)	3.6	66.8
5	20.4	30.6	–	−1.22±0.10	0.93 (57)	3.0	45.7
6	30.6	41.6	–	−1.5 ±0.3	0.88 (57)	2.0	9.9
XRT 1	23.2	28.7	5.73±4.2	−1.19±0.1	0.77 (62)	3.5	–
2	28.7	36.9	5.5±2.5	−1.34±0.08	0.98 (95)	2.5	–
3	36.9	50.6	3.4±2.2	−1.33±0.08	0.78 (89)	1.3	–
4	50.6	58.8	7.7 ±4.5	−1.85±0.1	1.12 (56)	1.4	–
5	58.8	67.1	4.2±2.0	−1.50±0.09	1.14 (73)	1.7	–
6	67.1	79.8	1.5±1.4	−1.86±0.13	0.94 (37)	0.54	–
7	79.8	159.4	<6.4	−1.80±0.15	1.12 (23)	0.12	–
8	159.4	244.4	<6.4	−1.97±0.24	0.90 (7)	0.05	–
9	628	848	<5.2	−1.80±0.24	0.92 (7)	0.02	–
10	848	1040	<6.8	−1.86±0.14	0.90 (35)	0.08	–
11	1452	1863	<5.8	−2.01±0.22	0.80 (17)	0.02	–
12	2275	2618	<6.9	−1.90±0.14	1.26 (47)	0.04	–
13	3045	8173	<4.0	−1.97±0.12	1.24 (35)	0.008	–

If Con-X could get on GRBs in ~ 2 hrs (versus 12-24 hours), gain factor ~ 100+ in flux.

Cusumano et al. (2007) claim to detect X-ray absorption in GRB 050904. Broadly consistent with absorption in other GRBs at lower redshift.

Con-X Simulation of GRB from a First Star



Simulated Con-X observation of a z ~ 10 GRB, motivated by properties of GRB 050904.

Assumed Con-X can observe starting ~ 2 hours after the GRB.

Might still work ~ 4-6 hours after burst if lucky.

Absorption lines from z ~ 10 host galaxy clearly detectable - metal enrichment of first galaxies and outflow kinematics.